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GRAIN-SIZE DISTRIBUTIONS IN LAKE MICHIGAN, 1977-81

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TABLE OF CONTENTS

FIGURES

TABLES

GRAIN-SIZE DISTRIBUTIONS IN LAKE MICHIGAN, 1977-81*

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The grain-size distributions of suspended material collected from Lake Michigan were measured with a HIAC particle counter. The Lake Michigan samples appear to have relatively more large particles than do oceanic samples, but the difference may be due to diffeences in the instruments used to measure the particles.

1. INTRODUCTION

This report presents particle concentration measurements made in Lake Michigan and the Grand River during 1977, 1978, 1979, and 1981. All measurements were made with a HIAC particle counter with either 5 or 12 channels. The machine uses a light blocking technique to measure particle size and reports particle concentrations for each of several size ranges--one per channel. Only those samples for which a total suspended material measurement (determined by filtration) is also available are reported. Since all of the measurements were made as parts of other studies, no interpretations of the data are included in this report although a brief discussion of the results is included.

2. PROCEDURE

Water was collected at the specified depths at each station in 5-liter Niskin bottles, of which two liters were filtered through pre-weighed glass fiber filters to determine the total suspended sediment concentration. A HIAC machine with five channels: 2-4, 4-8, 8-16, 16-32, and 32-60 μm (diameter) was used during 1977, 1978, and 1979. Two samples (sometimes three) of between 4 and 7 ml each were analyzed for each depth. The 1977 samples were collected as part of an investigation of the Grand River plume; locations of the stations used are given in figure 1. Locations of the 1978 stations are given in figure 2. All except the September 16 samples, which were collected as ground truth for the calibration of a NASA satellite, were collected in association with the deployment or recovery of sediment traps. These traps, which were also deployed in 1979, were part of an investigation of the bottom nepheloid layer (Chambers and Eadie, 1981).

In 1979 samples were taken at station 7 (fig. 3) on each of the days listed. In addition, samples were taken along two cross-lake transects. The first transect, sampled on August 23, was part of a joint NOAA-University of Michigan project to determine the spatial distribution and composition of suspended materials in southern Lake Michigan (Rea, Owen, and Meadows, 1981; Harrsch and Rea, 1982). The second transect, sampled on

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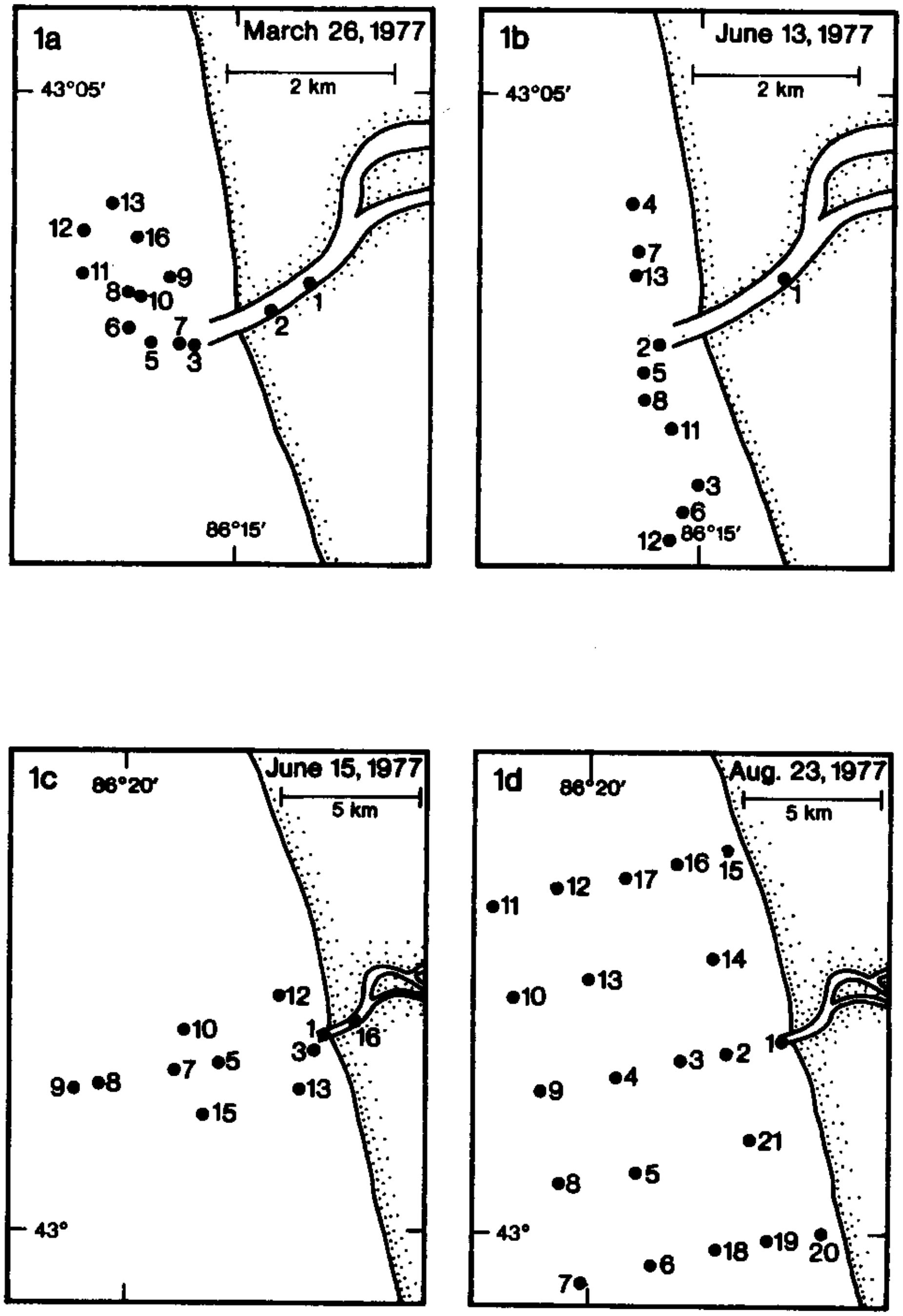
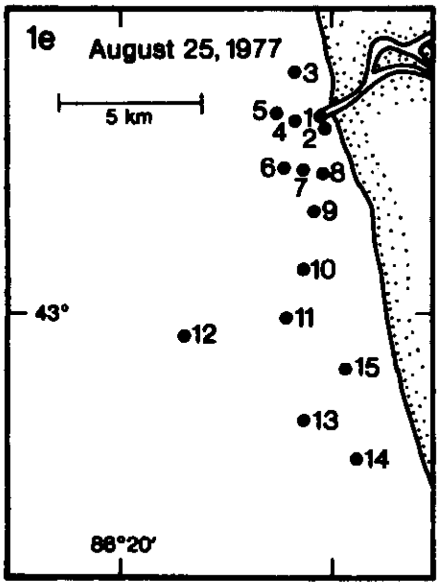


FIGURE 1.—*Location of 1977 stations.*
a) March 26, b) June 13, c) June 15, and d) August 23.



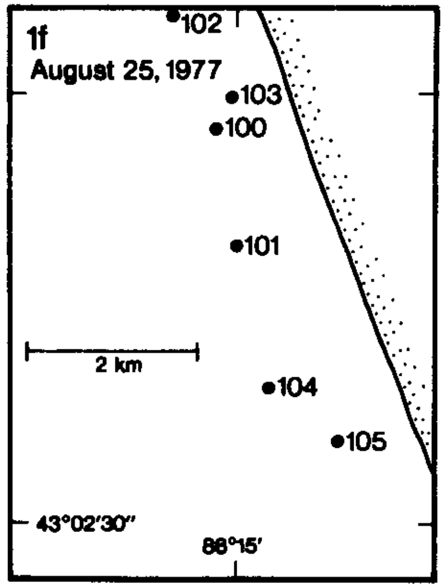


FIGURE 1. (cont.)—*Location of 1977 stations. e) and f) August 25.*

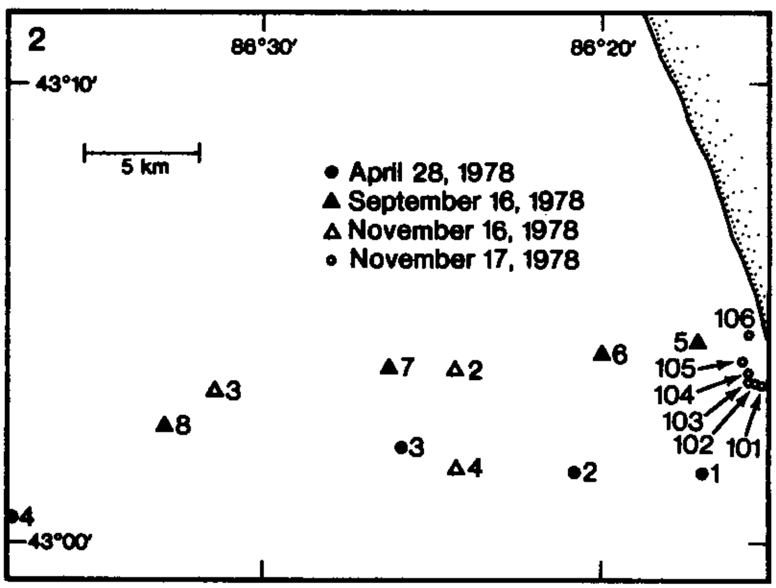


FIGURE 2.—*Location of 1978 stations. Station 101 is just off Grand Haven.*

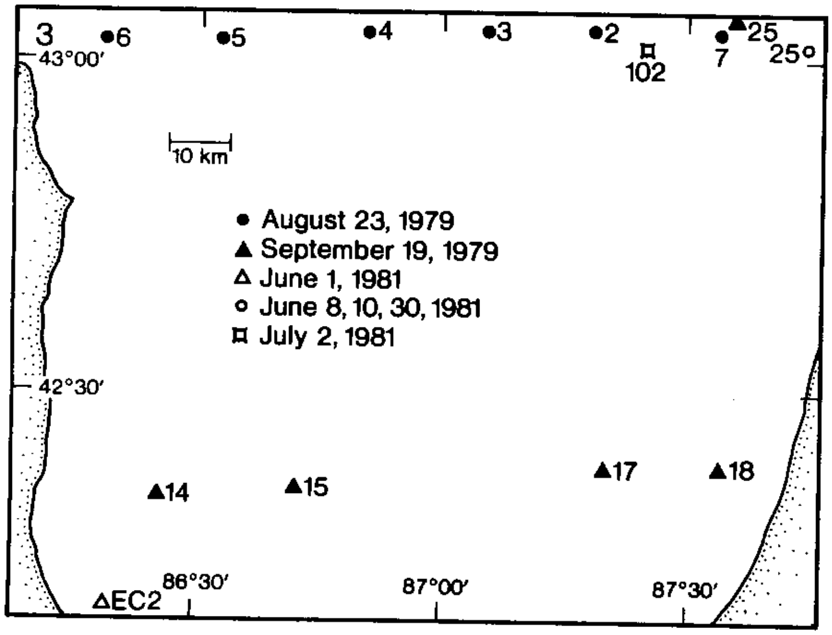


FIGURE 3.--*Location of 1979 and 1981 stations. Samples were taken at station 7 on May 9, May 30, August 11, September 19, and October 16, 1981. Station 25 (1981) is just off Grand Haven.*

September 19, was used to investigate the bottom nepheloid layer. The original data for the May 9 and May 30 observations have been lost. Since only the average values are available, the standard deviations have been set to zero. The above measurements are given in appendix A.

The 1981 samples were collected to calibrate a mathematical model of particle aggregation and rupture (Hawley, 1983). A HIAC machine with twelve channels whose boundaries could be varied was used to make replicate casts at 1-h intervals on several days. During early June, when a sensor operating between 1.0 and 60.0 μm was used, three 25-ml samples were analyzed at each depth for 11 size ranges: 1-2, 2-4, 4-8,.8-12, 12-16, 16-20, 20-24, 24-28, 28-32, 32-40, and 40-48 μm. A sensor operating between 2.5 and 150 μm was used to analyze the samples collected in late June and July. Two sets of size ranges were used for most samples: 2.5-4, 4-8, 8-12, 12-16, 16-20, 20-24, 24-28, 28-32, 32-64, 64-96, 96-128, and 2.5-4, 4-32, 32-40, 40-48, 48-56, 56-64, 64-80, 80-96, 96-112, 112-128, 128-144 μm. With the exception of the last series of measurements on July 2, when only two replicates were done, three 50-ml samples were analyzed at each depth. These measurements are listed in appendix B.

3. RESULTS

In all, 343 samples were analyzed during 1977-1979 and 103 in 1981: 34 with the 1- to 60-μm sensor and 69 with the 2.5- to 150-μm head. The precision of the results varies depending on both the sensor used and the size interval. The 1977-79 samples showed the best overall precision; for each size interval, the average ratio of sample standard deviation to sample mean was less than 10 percent (table 1). Results were also quite good for the smaller size intervals measured with the 2.5- to 150-μm sensor, but the precision decreased markedly for the larger size intervals. The 1- to 60-μm sensor gave the worst results.

Much of the variability in precision is due to the small numbers of particles counted in the larger size classes, which leads to large standard deviations and low means. The high ratios shown for the larger size intervals measured with the 2.5- to 150-μm sensor are at least partially due to the small number of particles counted. This also helps explain the poor precision of the results from the 1- to 60-μm sensor. For some reason, far fewer particles were counted with this sensor than with the others. Why this happened is unclear since the total suspended material measurements do not show a significant decrease.

Previous authors have noted that the size distribution of particles suspended in both the atmosphere and in the ocean can be described by a power law

$$n = ad^{-b} \ , \tag{1}$$

where n is the number of particles larger than d, the diameter in microns. McCave (1975) suggested that most marine suspensions have values of b between 2.4 and 3.6. Results for the lake samples are summarized in table 2 for r, a coefficient denoting the goodness of the fit ($r = 1.0$ indicates exact fit), equal to 0.80 and 0.90. As may be seen, for the 1977-79 Lake Michgian samples the average value of b is less than that for marine samples, indicating that there are relatively more large particles in Lake Michigan than in the ocean. All of the 1981 samples, however, have values of b similar to those found in the ocean. Values of a vary widely; those using the 1- to 60-μm sensor are similar to marine samples. It seems likely that the 1981 samples more accurately reflect the true size distribution since the sample volume was larger, but an examination of the 1981 data shows that the distributions are affected not only by the sensor used, but also by the size intervals measured.

Figure 4 shows the distribution of b for both the 1- to 60-μm and 2.5- to 150-μm sensor used in 1981. As can be seen, the values obtained with the 1- to 60-μm sensor and the first set of size intervals for the 2.5- to 150-μm sensor are fairly similar. Both have modes between 2.8 and 3.2. In contrast, the second set of size intervals for the 2.5- to 150-μm sensor has a distinctly lower mode (2.5) and no values above 2.8. If the sets of size intervals are combined (using measurements from the first set for particles less than 32 μm in diameter and measurements from the second set for particles greater than 32 μm), the results are similar to those using the first set of intervals only. Combining the sets also improves the general precision of the regressions. There are some difficulties with combining data from the two sets of observations, however. Both sets of observations had a size interval of 2.5- to 4-μm, but in most cases these observations do not match. An analysis of variance using the F test showed that all but two of

TABLE 1.—*Average ratio of sample standard deviation to sample mean. (Number of observations for each channel is given in parentheses).*

Sample period	Channel 1	2	3	4	5	6	7	8	9	10	11
1977–79	0.0497 (343)	0.0283 (343)	0.0347 (343)	0.0443 (343)	0.0806 (343)	-	-	-	-	-	-
June 1-10, 1982	0.0442 (34)	0.0374 (34)	0.0555 (34)	0.0920 (34)	0.1537 (34)	0.2303 (32)	0.3600 (15)	0.5267 (3)	0.3200 (1)	-	-
June 30–July 2, 1982 (First setting)	0.0125 (69)	0.0145 (69)	0.0197 (69)	0.0271 (69)	0.0363 (69)	0.0492 (69)	0.0542 (69)	0.0604 (69)	0.1586 (29)	-	-
(Second setting)	0.0184 (69)	0.0655 (69)	0.0930 (69)	0.1566 (66)	0.2192 (44)	0.1864 (33)	0.0767 (3)	0.1000 (1)	-	-	-

TABLE 2.--*Summary of regression statistics*

	R = 0.80			R = 0.90		
Sample period	# Samples	*a*	*b*	# Samples	*a*	*b*
1977-79	340	68054	-2.06	257	66883	-2.10
June 1-10, 1982	34	3768	-2.92	26	4177	-2.96
June 30-July 2, 1982 (1st setting)	45	317768	-3.17	1	-	-
(2nd setting)	60	8376	-2.42	0	-	-
(Combined settings)	68	368757	-3.09	8	317916	3.09

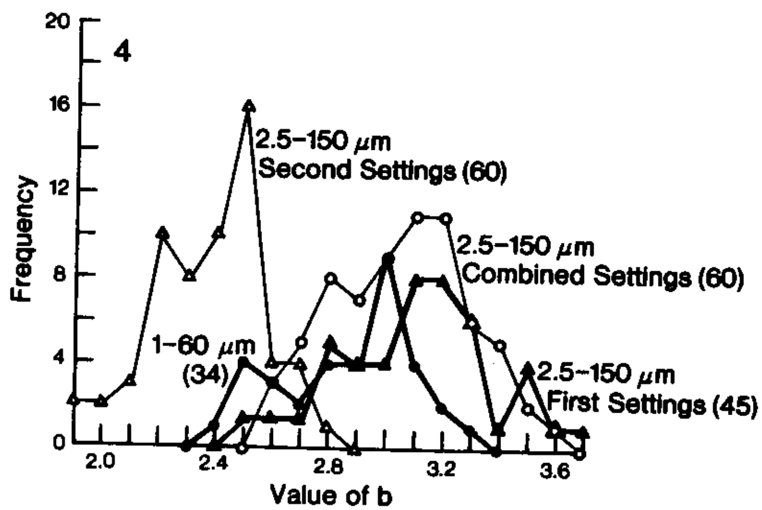


FIGURE 4.--*Histograms for the 1981 samples of the distribution of* $\underline{b}$ *in equation (1) for* $\underline{r}$ *= 0.80. Numbers in parentheses are the number of samples.*

the samples (excepting those collected on the final cast at station 102 on July 2, 1981) were significantly different at the 95-percent confidence level. The difficulty was traced to the sampling technique. For the above-mentioned samples, one aliquot of water was poured into the sampling chamber and three repetitions done for a single set of size intervals; then more water was added and the other size intervals were measured. For the third cast on July 2, only two repetitions were done for each set of size intervals, but no water was added. The F-test showed all of these samples to be the same at the 95-percent confidence level. Apparently the act of pouring the water into the sample container caused enough agitation to significantly alter the number of small particles. This suggests that the larger particles are only weakly bound. However, even for the last July 2 cast, the lack of agreement between, for instance, the 32- to 64-µm channel in the first setting, and the sum of the 32- to 40-µm, 40- to 48-µm ,48 to 56-µm, and 56- to 64-µm channels in the second setting is striking. Invariably the sum of the smaller range channels greatly exceeds the total in the large range channel. The converse is also true, i.e., the sum of the 4-8, 8-12, 12-16, 16-20, 20-24, 24-28, and 28-32 channels is much larger than the measurement made using one channel for the range 4-32. Why this occurs is totally mystifying. Unfortunately, since the HIAC machine was rented, it has not been possible to investigate this problem further. There is also no explanation for why the 1977-79 distributions vary so markedly from the 1981 samples.

4. CONCLUSIONS

Over 400 water samples collected between 1977 and 1981 in Lake Michigan and the Grand River have been analyzed for total suspended material and particle size distribution. Regression fits to equation (1) show that the 1977-79 samples have average values of a and b very different from those of marine and atmospheric samples. The 1981 samples have values of b similar to those of oceanic samples, but the values of a vary widely. The differences between the 1977-79 and 1981 samples may have been caused by differences in sampling technique and in the instruments used. There is no satisfactory explanation for the wide variability in the 1981 samples, but the results using the 2.5- to 150-µm sensor with the first set of size intervals is probably the most accurate.

5. REFERENCES

Chambers, R. L., and Eadie, B. J. (1981): Nepheloid and suspended particulate matter in southeastern Lake Michigan. *Sedimentology* 28:439-447.

Harrsch, E. C., and Rea, D. K. (1982): Composition and distibution of suspended sediments in Lake Michigan during the summer. (Submitted to *J. Great Lakes Res.*)

Hawley, N. (1982): A numerical model of cohesive suspended sediment dynamics, NOAA Tech. Memo. ERL GLERL-XXX, available from The National Technical Information Service, Springfield, Md. 22151. xx pp.

McCave, I. N. (1975): Vertical flux of particles in the ocean. *Deep-Sea Res.* 22:491-502.

Rea, D. K., Owen, R. M., and Meadows, G. A. (1981): A flux model for suspended particulates and associated chemical substances in large lakes, report of the Long Range Effects Cooperative Program established between The University of Michigan, Great Lakes and Marine Waters Center, and The National Oceanic and Atmospheric Administration, Great Lakes Environmental Research Laboratory, available from The National Technical Information Service, Springfield, Md. 22151. 63 pp.

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